

German Patent No. 94 21 671 U1

Job No.: 598-83353

Ref.: 004223 USA/ETCH/SILICON/JB

Translated from German by the Ralph McElroy Translation Company
910 West Avenue, Austin, Texas 78701 USA

FEDERAL REPUBLIC OF GERMANY
GERMAN PATENT OFFICE
UTILITY MODEL NO. 94 21 671 U1
(Gebrauchsmuster)

Int. Cl.⁶:

H 01 J 37/32
H 05 H 1/00
H 01 L 21/3065

Filing No.:

G 94 21 671.1

Filing Date:

August 26, 1994

Continuation from Patent Application:

P 44 30 385.8

Registration Date:

July 11, 1996

Publication in Patent Bulletin:

August 22, 1996

DISCHARGE CHAMBER FOR A PLASMA ETCHING SYSTEM USED IN
SEMICONDUCTOR FABRICATION

Holder:

Siemens AG, 80333 Munich, DE

The invention pertains to a discharge chamber for a plasma etching system used in the fabrication of integrated semiconductor circuits. The invention also pertains to the use of certain materials as an etching-gas-resistant wall material for such a discharge chamber.

For realizing the structure of thin layers with current semiconductor engineering, primarily plasma-based dry etching methods are used. In these methods, a plasma is created in a reactor which has an etching gas flowing through it by a generator usually operating in the high frequency range. In general, there are uncharged etching gas particles, ionized etching gas species and highly reactive neutral fragments (radicals) of the etching gas in the plasma. The known plasma-based etching methods can be essentially classified into the following two categories.

While RIE (Reactive Ion Etching) processes mostly use ionized etching gas species which are accelerated in an electric field onto the wafer to be structured, downstream methods use only radicals for removal of material. Since the etching reaction in downstream systems must occur spontaneously, primarily fluorine-containing etching gases are used. Due to the absence of

accelerated particles impacting the substrate with high energy, a very gentle material removal is achieved and the existing layer is not damaged (damage-free etching). Furthermore, layers can be removed very selectively, that is, one layer will be removed entirely, while the layer underneath will not be attacked. The disadvantage of downstream methods in comparison with RIE methods is the fact that the etching is fully isotropic, i.e., the etching attack does not have any preferred direction. The structure of an etching mask thus cannot be transferred 1 to 1 to the layer underneath.

In order to avoid exposure to high-energy particles, the plasma generation must be locally separated from the reactor. In the known technical configuration of the downstream method, the plasma and thus the required radicals are generated in a special discharge chamber, and from this chamber the radicals are directed into the actual etching chamber containing the wafers to be structured are found. The discharge chamber is usually designed as a tube in which the power generated by the RF-generator is injected. The major difficulty in the design of all plasma etching systems with this kind of discharge chamber or with a discharge tube is the selection of materials. The used material must be able to transmit the injected high-frequency power, that is, no metallic materials can be used. Since the discharge chamber must be resistant to the mostly very aggressive radicals of the etching gas, the use of plastics is also problematic. Another requirement of the discharge chamber is that it must be temperature resistant up to about 1000°C, which is necessary due to the heating of the discharge chamber during operation.

At the present time, discharge chambers or tubes are mostly made of quartz (SiO_2). SiO_2 can transmit RF power and is sufficiently heat-resistant. However, it exhibits a rather insufficient resistance to the aggressive etching gas radicals. Therefore, the discharge tube in these systems must be replaced after a few hours of operation due to wear (material removal).

Therefore the present invention is based on the problem of creating a discharge chamber of the kind described above which satisfies all the stated requirements of this kind of discharge chamber and which is more resistant to etching gas than the known discharge chambers.

This problem is solved in that the discharge chamber consists of a ceramic material or a monocrystalline material with the same chemical composition as the ceramic material.

Refinements of the invention are the topic of the subordinate claims. Advantages and details of the invention will be explained in greater detail below based on the following embodiment which uses the isotropic dry etching systems CDE VII and CDE VIII of Tylan-Tokuda Co., but the invention is not limited to these types of systems.

In known systems currently on the market, the processing plasma is generated in special quartz discharge tubes and flows through a roughly 1 m-long U-shaped line into the etching chamber. The quartz tubes have a length of 700 mm, an outside diameter of 38 mm and an inside diameter of 29 mm. Thus the wall thickness is 4.5 mm. Due to the low resistance of quartz to the

fluorine-containing etching gases used, the discharge tube must be replaced after only 10 plasma-hours. Since the material removal occurs primarily at one particular location, it is possible to clean the tube after its removal and to reinstall it rotated by 90°. With a symmetrical installation of the tube (injection site in the middle) a new tube must be used after 40 plasma-hours, and in the case of asymmetrical installation, after 80 plasma-hours. Every cleaning is associated with a considerable expense for labor and process controls. Furthermore, the up-time of the system is reduced. The resulting costs are considerable.

In tests with different kinds of materials it has been shown that ceramic materials are most suitable with regard to resistance to etching gas, heat resistance and transmission of RF power. Furthermore, monocrystalline materials can be used which have the same chemical composition as the ceramic. One compound that proved to be particularly suitable was aluminum oxide (Al_2O_3). To produce the ceramic, aluminum oxide spheres were compressed under high temperature and pressure. The monocrystalline modification (α - Al_2O_3 , corundum; or when doped with metal oxides, sapphire or ruby) is obtained, for example, by zonal refining from the melt. By testing Al_2O_3 ceramic tubes, their resistance to etching gas radicals and their temperature resistance can be demonstrated.

But as it turns out, it is not possible to use ceramic discharge tubes with the same dimensions as the quartz tubes.

The most important parameter is the wall thickness. With an unchanged 4.5 mm wall thickness, problems occur with the RF power injection (reflected power is too great) and with thermal stresses in the ceramic (cracks). One remedy is to reduce the wall thickness. In principle, it would be best to use the thinnest possible tubes. However, due to the 700 mm tube length, it is exceptionally difficult to achieve wall thicknesses of less than 2 mm using this technology. For a 2 mm wall thickness, the reflected power is indeed still somewhat greater than for the quartz tubes (30 W in comparison with 20 W), but it is still far below the tolerable limit of 8 W. Thermal stresses that result in cracks were no longer observed at a 2 mm wall thickness.

Overall, therefore, wall thicknesses in the range of 0.8 to about 3 mm can be used.

In the implementation using ceramic tubes, it should also be taken into account that ceramic has a rougher surface than quartz. Since the tube is used as part of a vacuum system, it is recommended to use ground tube ends onto which the gaskets are placed. The additional ignition aid (lamp) that is used in quartz tubes is not very practical for ceramic tubes, since the ceramic is only partially transparent. In the case of thin ceramic tubes, there are no problems, but to increase the dependability it is possible to install an ignition lamp in the tube flange on the gas inlet side.

The tubes of ceramic can be used for a minimum of 300 h (compared to 10 h for quartz tubes). Longer service life is easily possible; during the standard scheduled maintenance, the

tubes can be replaced as a preventive measure if desired. It is also an advantage for the ceramic tubes to exhibit a far lower particle load than the quartz tubes, where the particle reduction amounts to as much as 75%.

Other suitable materials are, for example, zirconium oxide (ZrO_2), magnesium oxide (MgO), calcium oxide (CaO) and yttrium oxide (Y_2O_3) for use as a ceramic or as a monocrystal. The invention is by no means limited to the use of traditional silica-containing ceramics. Other ceramic materials made of oxides, silicides or carbides of metals like those produced in modern powder metallurgy by pressing and sintering to form shaped elements can be used, or also boron carbide (B_4C) or silicon carbide (SiC). Also anisotropic etching processes or etching of a photoresist can be implemented with the plasma etching system modified according to this invention.

Claims

1. Discharge chamber for a plasma etching system used in the fabrication of integrated semiconductor circuits, characterized in that the discharge chamber consists of a ceramic material or a monocrystalline material with the same chemical composition as the ceramic material.
2. Discharge chamber for a plasma etching system according to Claim 1, characterized in that the discharge chamber consists of aluminum oxide (Al_2O_3).
3. Discharge chamber for a plasma etching system according to Claim 2, characterized in that the wall thickness of the discharge chamber is selected to be in the range of 0.8 to about 3 mm.
4. Discharge chamber for a plasma etching system according to one of Claims 1 to 3, characterized in that the discharge chamber is designed as a discharge tube which is connected to a separate etching chamber.
5. Use of a ceramic material or of a monocrystalline material with the same chemical composition as the ceramic material from the group of aluminum oxide, zirconium oxide, magnesium oxide, calcium oxide, yttrium oxide, boron carbide or silicon carbide as an etching-gas-resistant wall material of a discharge chamber for a plasma etching system used in the fabrication of integrated semiconductor circuits.